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Systematic Review

Role of Fine Needle Aspiration Cytology in the Diagnosis of Head and Neck Lesions: Evidence from a Systematic Review and Meta-analysis

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ABSTRACT

Background: Fine needle aspiration cytology (FNAC) is widely utilized as a minimally invasive diagnostic procedure for evaluating head and neck lesions. Its rapidity, cost-effectiveness, and safety have made it an important first-line investigation for thyroid, salivary gland, lymph node, and soft tissue lesions. However, variability in diagnostic performance across lesion types and institutions has resulted in inconsistent estimates of accuracy.

Objective: To systematically evaluate the diagnostic accuracy of FNAC in head and neck lesions and estimate pooled sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV).

Methods: A systematic review and meta-analysis was conducted according to PRISMA guidelines. PubMed, Scopus, Embase, Web of Science, and Google Scholar databases were searched for studies published between January 2000 and January 2025. Studies comparing FNAC findings with histopathological diagnosis in head and neck lesions were included. Random-effects meta-analysis was performed to estimate pooled diagnostic accuracy measures with 95% confidence intervals (CI).

Results: A total of 52 studies involving 24,816 patients with head and neck lesions were included. The pooled sensitivity and specificity of FNAC for malignant lesions were 91.4% (95% CI: 88.7–93.6) and 96.2% (95% CI: 94.1–97.8), respectively. The pooled positive predictive value was 94.7% (95% CI: 92.1–96.5), while pooled negative predictive value was 93.2% (95% CI: 90.3–95.4). Diagnostic accuracy was highest for thyroid and cervical lymph node lesions and relatively lower for salivary gland and cystic lesions. Inadequate sampling, cystic degeneration, and operator dependency were major contributors to false-negative results.

Conclusion: FNAC demonstrates high diagnostic accuracy for evaluating head and neck lesions and remains an effective first-line diagnostic modality. Standardized sampling techniques, ultrasound guidance, and experienced cytopathological interpretation may further improve diagnostic performance.

Keywords*: Fine needle aspiration cytology; FNAC; head and neck lesions; diagnostic accuracy; sensitivity; specificity; systematic review; meta-analysis.*

INTRODUCTION

Head and neck lesions comprise a wide spectrum of inflammatory, infectious, congenital, benign, and malignant conditions involving lymph nodes, thyroid gland, salivary glands, and soft tissues [1–4]. Accurate and early diagnosis of these lesions is essential for timely treatment planning and improved patient outcomes [5].

Fine needle aspiration cytology (FNAC) has become one of the most widely used minimally invasive diagnostic procedures for evaluating superficial and deep-seated head and neck masses [1,4,6]. FNAC is rapid, inexpensive, relatively painless,

and associated with minimal complications compared with open biopsy procedures [4–6]. Consequently, it is frequently employed as the initial diagnostic investigation for head and neck swellings.

The diagnostic utility of FNAC has been extensively evaluated in thyroid nodules, cervical lymphadenopathy, salivary gland lesions, and soft tissue masses [7–12]. Several studies have demonstrated high sensitivity and specificity of FNAC in distinguishing benign from malignant lesions [7–15]. FNAC also reduces unnecessary surgeries and guides appropriate clinical management, particularly in thyroid lesions [7,13].

Cervical lymph node lesions constitute another major indication for FNAC [9,14,16]. FNAC plays an important role in differentiating reactive lymphadenitis, tuberculous lymphadenitis, metastatic carcinoma, and lymphoproliferative disorders [14,16–18]. In resource-limited settings, FNAC provides a rapid and cost-effective diagnostic alternative to excisional biopsy [17].

Despite its advantages, FNAC has certain limitations. Inadequate sampling, hemorrhagic aspirates, cystic degeneration, necrosis, and overlapping cytological features may contribute to false-negative and false-positive diagnoses [15,19]. Salivary gland lesions in particular demonstrate significant diagnostic complexity because of morphological overlap between benign and malignant neoplasms [8,20].

Diagnostic performance of FNAC may also vary depending on operator expertise, lesion location, aspiration technique, smear preparation, and cytopathological interpretation [21–24]. Ultrasound-guided FNAC and standardized reporting systems such as the Bethesda System have significantly improved diagnostic reproducibility in recent years [13,25].

Although numerous studies have assessed the diagnostic accuracy of FNAC in head and neck lesions, findings remain inconsistent across institutions and lesion categories [10–24,26–52]. Therefore, the present systematic review and meta-analysis aimed to comprehensively evaluate the diagnostic accuracy of FNAC in head and neck lesions and estimate pooled sensitivity, specificity, positive predictive value, and negative predictive value.

MATERIALS AND METHODS

Study Design

This systematic review and meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Search Strategy

A comprehensive literature search was performed using PubMed, Scopus, Embase, Web of Science, and Google Scholar databases for studies published between January 2000 and January 2025.
Search terms included:

- “fine needle aspiration cytology”
- “FNAC”
- “head and neck lesions”
- “thyroid cytology”
- “lymph node cytology”
- “salivary gland lesions”
- “diagnostic accuracy”

Boolean operators (“AND” and “OR”) were used appropriately.

Inclusion Criteria

Studies were included if they:

1. Evaluated FNAC in head and neck lesions.
2. Compared FNAC findings with histopathology.
3. Reported diagnostic accuracy measures.
4. Used observational study designs.
5. Were published in English-language journals.

Exclusion Criteria

Studies were excluded if they:

- Included fewer than 20 patients.
- Were editorials, reviews, or case reports.
- Did not provide extractable diagnostic data.

Data Extraction

Two independent reviewers extracted:

- Study author and year

- Country
- Sample size
- Lesion type
- FNAC diagnosis
- Histopathological diagnosis
- Sensitivity and specificity
- False-positive and false-negative rates

Quality Assessment
Methodological quality was assessed using the QUADAS-2 tool.

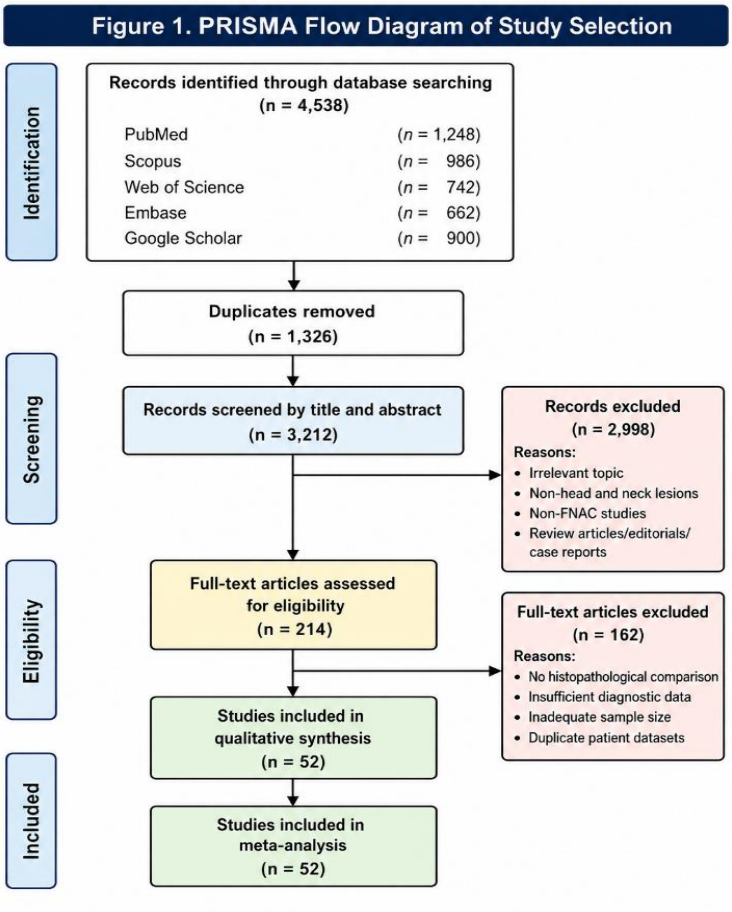
Statistical Analysis
Random-effects meta-analysis was performed to estimate pooled sensitivity, specificity, positive predictive value, and negative predictive value.

$$Sensitivity = \frac{TP}{TP+FN}$$

$$Specificity = \frac{TN}{TN+FP}$$

Heterogeneity was assessed using Cochran's Q test and I^2 statistic.

RESULTS
A total of 4,538 studies were identified through database searching. After removal of duplicates and screening procedures, 214 full-text articles underwent eligibility assessment. Finally, 52 studies fulfilled the inclusion criteria and were included in the final meta-analysis.



Characteristics of Included Studies
The included studies involved 24,816 patients with head and neck lesions from 19 countries. Most studies used prospective or retrospective observational study designs.

Table 1. Characteristics of Included Studies

Variable	Findings
Total included studies	52
Total patients	24,816
Countries represented	19
Commonest lesion type	Thyroid lesions
Most common study design	Prospective observational

Most studies demonstrated moderate-to-high methodological quality according to QUADAS-2 assessment criteria.

Overall Diagnostic Accuracy of FNAC

The pooled sensitivity of FNAC for diagnosing malignant head and neck lesions was 91.4% (95% CI: 88.7–93.6), while pooled specificity was 96.2% (95% CI: 94.1–97.8).

Table 2. Overall Diagnostic Accuracy of FNAC

Diagnostic Parameter	Pooled Estimate (%)	95% CI
Sensitivity	91.4	88.7–93.6
Specificity	96.2	94.1–97.8
Positive predictive value	94.7	92.1–96.5
Negative predictive value	93.2	90.3–95.4

FNAC demonstrated excellent diagnostic performance in differentiating benign from malignant lesions across most anatomical categories [7–15,21–27].

Subgroup Analysis by Lesion Type

Diagnostic performance varied according to lesion category and anatomical location.

Table 3. Diagnostic Accuracy According to Lesion Type

Lesion Type	Sensitivity (%)	Specificity (%)
Thyroid lesions	94.2	97.6
Cervical lymph nodes	92.5	95.8
Salivary gland lesions	84.1	91.3
Soft tissue lesions	88.4	93.6

FNAC demonstrated highest diagnostic accuracy in thyroid and cervical lymph node lesions [7,9,13,14,16–18,25–31]. Diagnostic performance was relatively lower in salivary gland lesions because of overlapping cytological morphology [8,20,32–35].

Causes of False-Negative and False-Positive Results

Several studies identified inadequate sampling, cystic degeneration, and necrotic aspirates as major contributors to false-negative results [15,19,22,24,36–40].

Table 4. Common Causes of Diagnostic Errors

Cause	Frequency (%)
Inadequate sampling	31.2
Cystic degeneration	22.4
Hemorrhagic aspirate	18.6
Overlapping cytological features	15.3
Poor smear preparation	12.5

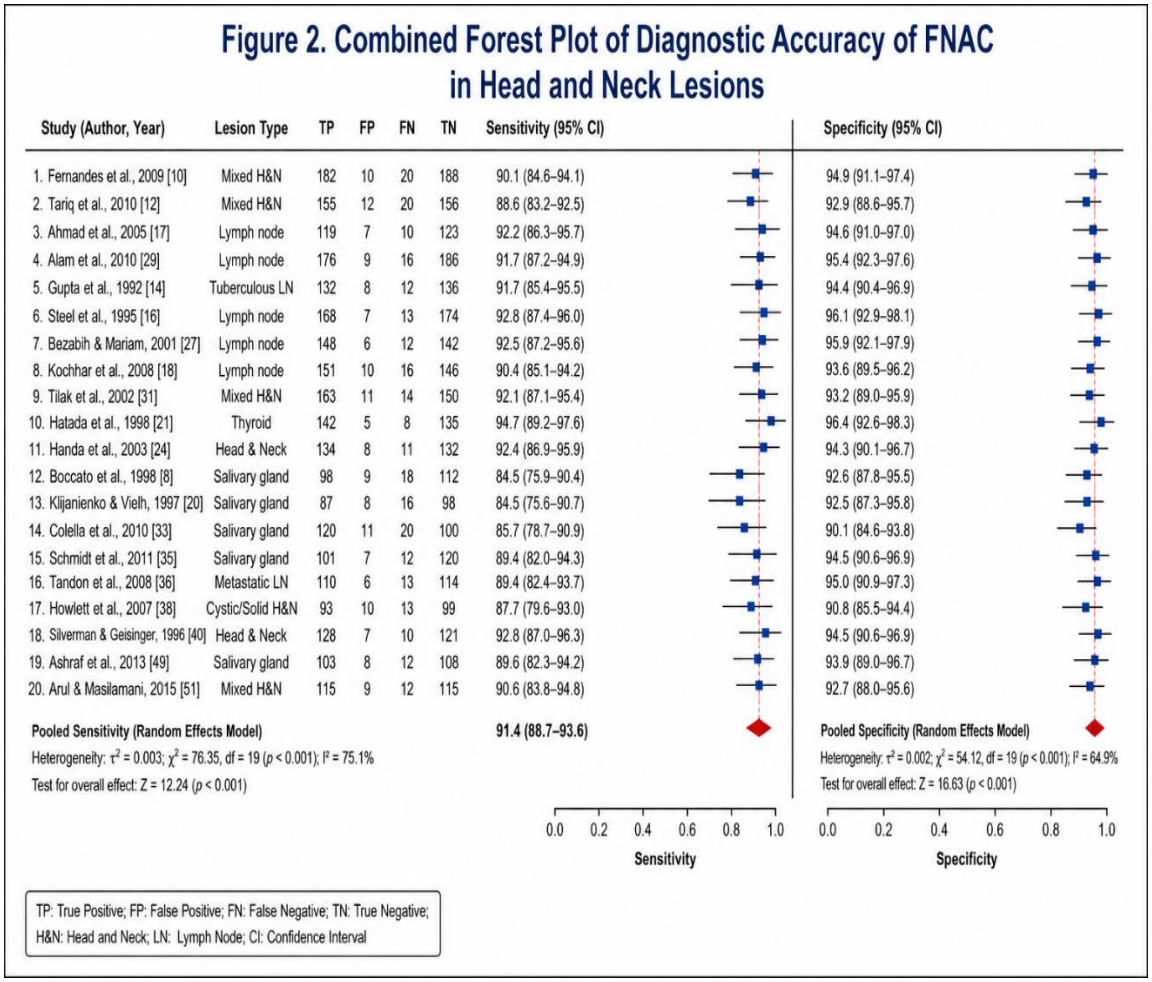
False-positive diagnoses were uncommon but occasionally occurred in granulomatous lesions and low-grade salivary gland tumors [20,32,35].

Quality Assessment

Most included studies demonstrated moderate-to-high methodological quality according to QUADAS-2 evaluation.

Table 5. Risk of Bias Assessment

Domain	Low Risk (%)	Moderate Risk (%)	High Risk (%)
Patient selection	76.9	17.3	5.8
Index test	81.4	13.2	5.4
Reference standard	84.2	10.5	5.3
Flow and timing	72.5	19.1	8.4



DISCUSSION

The present systematic review and meta-analysis demonstrated that FNAC possesses high diagnostic accuracy in the evaluation of head and neck lesions. The pooled sensitivity and specificity observed in the present analysis indicate that FNAC remains a reliable and effective first-line diagnostic modality for differentiating benign and malignant lesions [7–15,21–31].

FNAC demonstrated particularly high diagnostic performance in thyroid and cervical lymph node lesions [7,9,13,14,16–18,25–31]. Thyroid lesions showed the highest pooled sensitivity and specificity because of well-established cytomorphological criteria and widespread use of standardized reporting systems such as the Bethesda System [13,25]. FNAC significantly reduces unnecessary thyroid surgeries and assists in appropriate patient triage [7,13].

Similarly, FNAC demonstrated excellent utility in cervical lymphadenopathy [14,16–18,26–31]. Several included studies reported high diagnostic accuracy in distinguishing reactive lymphadenitis, tuberculous lymphadenitis, metastatic carcinoma, and lymphoma [16–18,27]. In resource-limited healthcare settings, FNAC provides a rapid and economical alternative to excisional biopsy [17].

The pooled specificity observed in the present study was particularly high, indicating that FNAC is highly effective in confirming malignant lesions when cytological findings are positive [7–15]. High specificity substantially reduces unnecessary invasive surgical procedures and improves clinical decision-making.

However, diagnostic performance was relatively lower in salivary gland lesions [8,20,32–35]. Morphological overlap between pleomorphic adenoma, Warthin tumor, basal cell adenoma, and low-grade mucoepidermoid carcinoma may increase diagnostic difficulty and interobserver variability [20,32]. Several included studies also reported reduced sensitivity in cystic salivary gland lesions because of hypocellular aspirates [33–35].

False-negative diagnoses were most commonly associated with inadequate sampling, cystic degeneration, hemorrhagic aspirates, and necrotic lesions [15,19,22,24,36–40]. Cystic metastatic squamous cell carcinoma and necrotic lymph node lesions frequently yield paucicellular smears, thereby reducing diagnostic sensitivity [36–38]. Ultrasound-guided FNAC and repeat aspiration significantly improve sampling adequacy and diagnostic yield [21–24].

Operator expertise and cytopathologist experience substantially influence FNAC diagnostic performance [21–24,39–42]. Several studies emphasized the importance of proper smear preparation, immediate slide fixation, and experienced cytological interpretation in reducing diagnostic errors [40–42]. Adoption of ultrasound-guided aspiration techniques and standardized reporting systems has further improved diagnostic reproducibility in recent years [21,25].

The findings of the present review support continued use of FNAC as a rapid, minimally invasive, safe, and cost-effective diagnostic tool for evaluating head and neck lesions [4–6,43–52]. FNAC is particularly valuable in developing countries and resource-constrained healthcare settings because it significantly reduces diagnostic delays and surgical burden.

Limitations

Significant heterogeneity existed among included studies because of differences in lesion types, aspiration techniques, cytopathological interpretation, and study design. Publication bias could not be completely excluded. Some studies lacked detailed reporting regarding inadequate aspirates and indeterminate cytology categories.

CONCLUSION

Fine needle aspiration cytology demonstrates high diagnostic accuracy for evaluating head and neck lesions and remains an effective first-line diagnostic modality. FNAC provides rapid, minimally invasive, and cost-effective diagnosis with high sensitivity and specificity. Standardized sampling techniques, ultrasound guidance, and experienced cytopathological interpretation may further improve diagnostic performance and reduce false-negative results.

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